LCA Case Studies

Life Cycle Analysis of the Newspaper Le Monde

Christophe Rafenberg, Eric Mayer

U.F. Environnement, University Paris 7 Denis Diderot, 2 place Jussieu, F-75251, Paris Cedex 05, France

Corresponding author: Prof. Eric Mayer; e-mail: mayer@ccr.jussieu.fr

Abstract

On behalf of the French press group Le MONDE, four newspapers have been examined in a Life Cycle Assessment study. The products were the newspaper actually produced and sold in 1995, two other 1995 versions with reduced amounts of unsold circulation and an improved version manufactured under adequate management control and using paper, inks, printing plates and packaging material with lower environmental impacts.

Results include the following:

- An improved distribution, reducing the unsold circulation by 40% and 80%, does not reduce significantly the relative effect score of the different environmental impacts because the effects of the internal management are predominant.
- The development of an improved version of Le MONDE depends more on managerial will than on technical decisions.
- The use of vegetal inks improves significantly the air quality inside the printing plant as well as the photochemical oxidant potential.

System boundaries and references are given in the paper.

Keywords: LCA, newspaper; Life Cycle Assessment (LCA), newspaper; newspaper, LCA; papers, LCA; printing press, newspaper, LCA; vegetal inks, newspaper, LCA

1 Introduction

More and more companies are discovering the value of identifying the environmental characteristics of their products or services, hoping to gain favour with the consumer. Advocacy groups are also interested, hoping that companies will operate in a more environmentally responsible manner if consumers are offered the opportunity to learn about the environmental characteristics of a company's products or services (and presumably act on their preferences by avoiding environmentally insensitive goods and services).

The Life Cycle Assessment (LCA) procedure provides an organization with a methodology for identifying and assessing the environmental impacts of a product or service throughout all stages of its life cycle, from new materials acquisition to final disposal or reuse [1,2,3]. A set of ISO standards is under development and will probably come out by the end of 1998. ISO 14040, already published, refers to the general principles and scope of LCA, ISO 14041, in the final approval phase, refers to the Life Cycle Inventory. ISO 14042 refers to Life Cycle Assessment while ISO 14043 will provide guidance for the LCA interpretation; ISO 14042 and ISO 14043 are still under discussion.

In 1998, more than a dozen LCA software are on the market as well as interpretation methods [4,5,9].

In the newspaper industry in France, few managers, if any, seem aware of the importance of any of these approaches. Before 1994, to meet the general demand for environmentally friendly manufacturing processes and products, neither ecolabeling nor Life Cycle Analysis had been considered.

In 1993-1994, the newspaper group Le MONDE, faced with admnistrative requirements for a better management of its waste and effluents, became conscious, that an appropriate response to increased consumer sensitivity, to environmental issues in France and in Europe, could affect positively its incomes. Simultaneously the group was looking for solutions to increase both the trade of some of its available services (printing facilities) and the newspaper circulation. It was then decided that, in order to gain an image of an environmental friendly company, it would be of interest for the group Le MONDE to improve the environmental characteristics of both the newspaper and the printing plant in Ivry near Paris.

This article is a summary of the study Life Cycle Assessment of the newspaper Le MONDE performed, between 1994 and 1997, on behalf of the press group Le MONDE by the University Paris 7 – Denis Diderot and the University of Orléans with the help of the National Association for Technological Research (ANRT) [6].

The examined objects are the newspaper, the printing plant and the distribution circuits.

Newspapers are indeed very peculiar products – obsolete even before they are sold – so time is an extremely impor-

tant factor. Every day, a newspaper is a new product which must be distributed in time and as quickly as possible following only sales predictions without knowing how many copies will effectively be bought.

Thus, even if the goal definition and scope of this study were fixed by the press group, the identification of the product and corresponding functional unit as well as the determination of the system boundaries were not an easy task, due mainly to the importance of external parameters not at all related to the printing plant operation.

2 Goal Definition and Scope

It was decided to use a Life Cycle Analysis to identify, assess and improve the environmental impacts of the daily newspaper Le MONDE (hereafter, referred to as the quotidien) throughout all the stages from paper mills through printing process, distribution circuits, consumer use to final disposal.

In the beginning, the objectives of the investigation were the following:

- to assess the environmental performances of the quotidien with respect to those environmental impact criteria for which quantifiable transformation rules from the Life Cycle Inventory (LCI) are available.
- to provide the press group with recommendations on how to reduce the environmental impacts due to the products and processes used in the printing plant operation.

The background intentions of the group press Le MONDE were:

- to assess the environmental situation of the printing plant after 6 years of operation.
- to identify which steps are required to reduce the increasing costs of waste management
  - either by some changes of the incoming products,
  - or by improvements of the production management.
- to improve the environmental image of the press group to attract new customers.

The quantitative results are intended for the exclusive use of the press group board of directors, while the methodology and more qualitative findings are part of the academic work of the PhD thesis of Mr. Rafenberg funded by the ANRT.

To avoid a conflict between the necessary confidentiality for Le MONDE specific data and the presentation of the results in a scientific journal, we report here, all data and the improvements which could be achieved, in percentage points of the maximum value.

2.1 The product under study

In Ivry, in 1995, the press group Le MONDE printed on a daily, weekly and monthly basis, different products such as: quotidien, Le MONDE diplomatique, Le MONDE des débats, Dossiers et Documents, La Sélection hebdomadaire du MONDE, Infomatin. Some of these products are not produced any more in 1998.

This work considers exclusively a full production year of the quotidien – 1995 – during which we counted 309 days of production and 2 days of strike with no circulation (→ *Fig. 1*).

To take into account the different productions, we considered both the paper consumption:

- 96.4% were used to produce the quotidien,
- 3.6% were used for the other newspapers and magazines.

and the total plant operation time:

- 74% of the total plant operation time were used to print the quotidien,
- 26% of this time were used to print the other publications.

The allocation of the inputs was done as follows.

- 96,4% of primary and secondary products have been allocated to the quotidien;
- 74% of the energies, fluids and wetting products have been allocated to the quotidien.

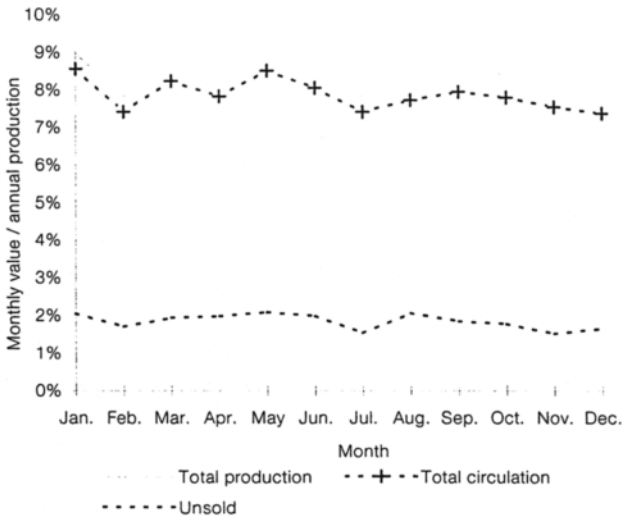

Fig. 1: Monthly circulation of Le MONDE in 1995

This work addresses three issues:

- What are the actual environmental impacts of the quotidien?
- How can the actual environmental impacts of the printing process be reduced?
- How can the actual environmental impacts of the distribution process be reduced?

It should be stressed that these impacts have very different relative importance.

2.2 The functional unit

In all product LCA's, the description of the functional unit is a key step. It is necessary to give a definition as accurate as possible in order to compare different product life cycle scenarii.

This is extremely difficult for a product whose characteristics (content, colours, number of pages, circulation, distribution ...) are both:

- seasonal – in summer the quotidien has about half the number of pages but a somewhat higher circulation – and
- erratical depending on special external events generally not related to the printing process: elections, wars, strikes...

Figure 2 reports the 1995 fluctuations of the number of pages not including the two days of strike.

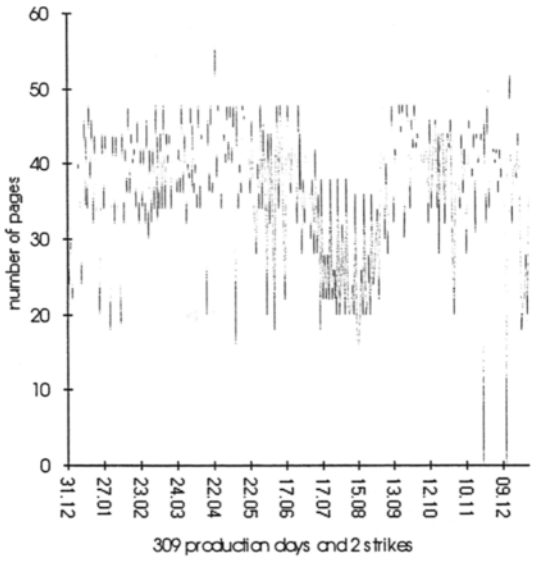

Fig. 2: Fluctuations of the number of pages of Le MONDE in 1995

After a thorough analysis of all these factors, we decided that the average quotidien:

- contains 38 pages with 2 pages in two-colour printing and 2 pages in four-colour printing,
- weighs 115.330 g. per sample (paper + inks).

The quotidien is printed in Ivry near Paris. The newspaper is then delivered, at the plant, to different independant operators which will sell it or give it to their customers. Considering 100 newspapers on the average [7] (→ *Fig. 3*):

- 72 are delivered to the NMPP (New Press Distribution Service in Paris) which distributes them in Paris and other big cities, (the unsold ones, 24 for every 100 newspapers printed, are recovered by NMPP and recycled)
- 22 are delivered by mail to subscribers mainly in France,
- 6 are delivered to big companies which give it out to their customers (SNCF, Air France,...).

Thus, for every 100 newspapers delivered by the printing plant, only 76 are sold. This is mainly due to the effective monopoly exerted, on newspaper distribution, by the NMPP.

In this study the functional unit will be the production of enough quotidien so that 76 copies are effectively sold.

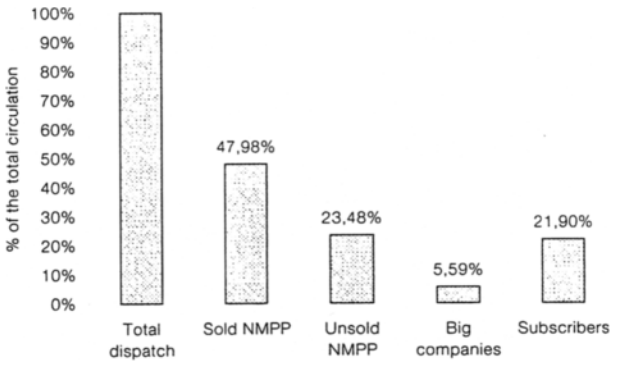

Fig. 3: Le MONDE distribution in 1995

2.3 System boundaries

In this study, the operations related to the impression, distribution, incineration, final disposal or recycling of the quotidien were reviewed.

The press group buys paper and other products in France and in different countries of Europe. We have investigated the transport of all inputs.

Not all the newspaper distribution process is known precisely; we cannot determine:

- how many newspapers are sent to Japan, Belgium or elsewhere by the Air-Line companies?
- how many newspapers are sent every day by the NMPP outside of Paris and to whom they are distributed?

Thus, to carry out a Life Cycle Analysis on the quotidien and on some of the press group Le MONDE operation procedures, we have defined the system boundaries as follows:

1. The life cycles of all system components – required by the printing of the newspaper, its preparation for delivery – were investigated from the production to the final disposal or recycling.
2. Energy supply and consumption use two models:
   - the European energetic model for all the products delivered to the plant,
   - the French energetic model for the printing plant.
3. Generic unit operations such as transportation have been simplified.

   The average distance between manufacturing plants and the printing plant has been estimated equal to 200 kilometers and
   - primary products, except for the aluminium printing plates and photosensitive films, are delivered by 42 tons trucks. Inks are supplied by tankers.
   - secondary products are delivered by 28 tons trucks.
   - the transportation to deliver the readers is not taken into account because the actual distribution in France and abroad is unknown.
   - the transportation, between readers and waste collectors, considers that the readers are mainly located in urban areas.
4. Incineration, final disposal and recycling of used papers was considered for France only.
5. Products or processes with no significant impacts, and for which no adequate data were available, were discarded.

2.4 Life Cycle Inventory (LCI) of the quotidien

Among the many LCA software packages available on the market, KCL-ECO with ECODATA database [8] was chosen because it offered a few data for the paper industry. It also allows an impact determination of the energy production and use in Europe and France knowing the fuel breakdown.

KCL-ECO also offers an advanced system flow diagram which highlights the relations between the different units: suppliers, printing plant, distribution circuits, final disposal. This was of great importance in our study.

The relatively low cost of this software compared to others in Europe [9] was also an issue.

Beside some data of the ECODATA database, our data sources include publicly available documents, published work and requested data from both the industry and government sectors about the products necessary for the operation of a newspaper printing plant [8,10-16]. Not all our data are site specific, however, from the confidential manufacturers security sheets made available to us, we got a lot of information on the products actually used in this printing plant.

Specific models have been developed for the vegetal inks. For these models, the system boundaries starts with the field cultivation including plowing, sowing, three distribution of phytosanitary products, harwesting, storage and ends with the oil production. The use of tractors and the transport of inputs and outputs have been considered. The risk of spilling during transportation exists but has been taken into account neither for the mineral oils nor for the vegetal oils.

Information to develop these models has been provided by INRA, CETIOM and ONIDOL [10] and also elaborated by the authors. The mineral oil model which considers extraction, transport and transformation, is an average model of APME [10] for oil refined and sold in France. For the phytosanitary products, whose total and active mass are known only, we use the average CML values [11] of the aquatic ecotoxicity (ECA) and of the terrestrial ecotoxicity (ECT) of the products usually applied by the French farmers.

The LCI of the quotidien starts with the production and imports of energies, fluids, paper and other products and ends with the incineration or disposal of used newspapers and other waste. A major step has been the determination of all inputs and outputs during a whole operation year – **Table 1** and **Figure 4.**

Primary and secondary products

The products inputs had to be separated into two categories .

The primary products list (→ *Table 2*) contains all the inputs without which the quotidien cannot be printed, i.e. paper, inks, photosensitive printing plates and photosensitive plastic films.

The secondary products list (→ *Table 3*) contains all those inputs required by:

- the operation and maintenance of the printing press,
- the operation and maintenance of the auxiliary generators,
- the preparation and packaging of the newspapers for distribution.

Table 1: Printing plant inputs and outputs

Inputs to the printing plant	Outputs of the printing plant
- Energies (electrical and thermal) - Fluids (water, compressed air) - Fuel for auxiliary generators and vehicles - Primary products - Secondary products	- Energy losses - Finished commercial products (newspapers...) - Fluids - Solid, liquid or gaseous plant effluents - Vehicle emissions between suppliers and plant - Vehicle emissions between readers and waste collectors - Waste
Inputs not included in the LCA analysis	**Outputs not included in the LCA analysis**
- Ancillaries for administrative work (computers, photocopying machines,...) - Buildings and infrastructures of the press group - Information - Infrastructures and inputs manufacturing plants - Internal facilities (restaurant, coffee machines) - Maintenance and safety equipments - Mechanical equipments (printing press,...) - Men - Vehicles to import or export the products	- Emissions due to biotic productions - Emissions due to the newspaper distribution - Information - Men - Noise - Odours - Vegetal residues

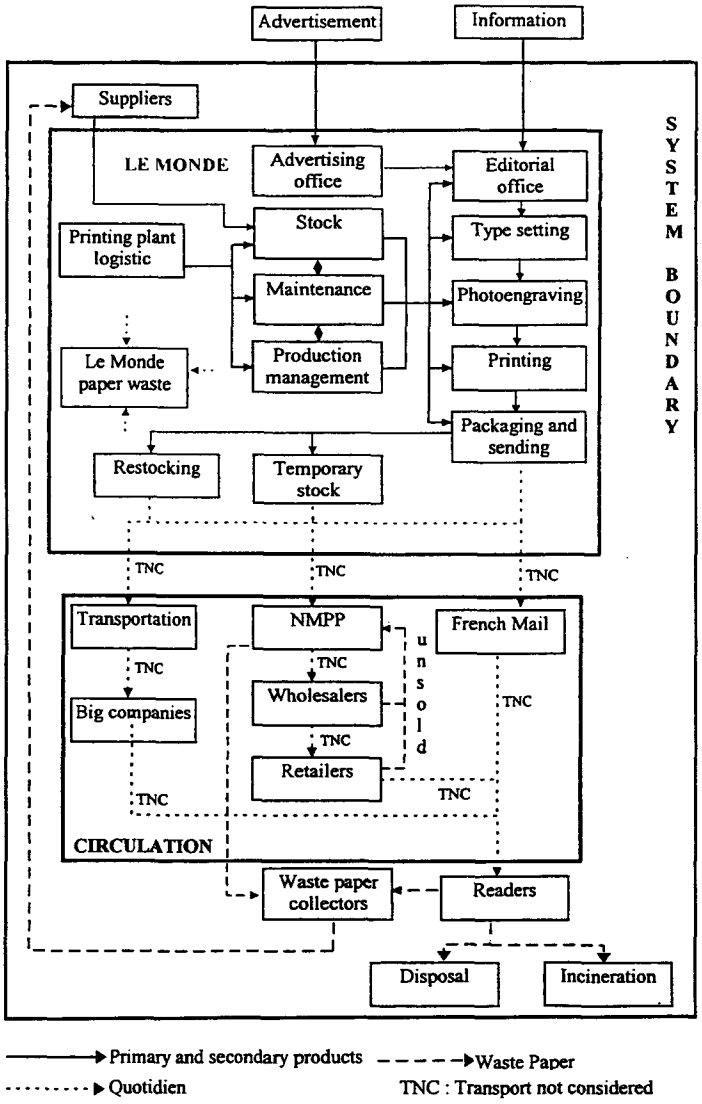

Fig. 4: Printing plant inputs and outputs flow diagram

Table 2: Primary products inputs in 1995

Product family	% of the total mass of primary products	Waste disposal procedure	Risk	Toxicity
paper rolls	99.12	recycling	no risk	not toxic
black inks	0.71	incineration	flammable	toxic
coloured inks	0.12	incineration	flammable	toxic
photosensitive aluminium plates	0.04	recycling	no risk	harmful
photosensitive papers	0.01	rubbish dump	no risk	harmful
photosensitive films	0.004	rubbish dump	no risk	Harmful

Risk: physical risk (fire, detonation, explosion)
Toxicity: human toxicity (based on manufacturers security sheets)

Table 3: Secondary products inputs in 1995

Family of generic products	% of the total mass of secondary products	Waste disposal procedure	Risk	Toxicity
solvents	23.14	incineration	very flammable	very harmful
detergents	4.78	dilution	flammable	very harmful
soaps	1.52	dilution	flammable	harmful
plastic packagings	24.22	rubbish dump	no risk	not toxic
metallic packagings	4.99	recycling	no risk	not toxic
greases	1.11	rubbish dump	flammable	very harmful
oils	3.01	rubbish dump	flammable	very harmful
wetting products	15.11	dilution	very flammable	toxic
photosensitive film and plate chemicals	11.70	dilution	no risk	very harmful
glues	0.04	rubbish dump	very flammable	very harmful
inks for mailing	0.05	rubbish dump	very flammable	toxic
bactericides & fungicides	0.52	rubbish dump	no risk	very harmful
rags	3.09	rubbish dump	dry: no risk wet: very flammable	dry: not toxic wet: very harmful
surface treatments	0.09	rubbish dump	flammable	very harmful
sprays	0.04	rubbish dump	very flammable	harmful
PEHD containers	0.52	rubbish dump	no risk	not toxic
carboard	1.31	rubbish dump	no risk	not toxic
metallic containers	3.36	recycling	no risk	not toxic
various	1.45	rubbish dump	no risk	not toxic

For most of the primary products, also treated separetely because of the huge amounts used each year (about 98.5% of the total inputs), we have a good knowledge of their origin, composition and environmental impacts.

Among the primary products, the photosensitive aluminium plates and the photosensitive films required by the printing process have been treated as follows. Every day, 200 plates and films are required to print 100, 1,000, 400,000 newspapers or none in case of strike. We decided to allocate the daily amount of plates and films to one functional unit. This decision amplifies the global environmental impacts of these plates and films and stresses the importance of a better waste management.

For the secondary products, the problem is more complex. After analysing the 1,600 product references consumed each year, identifying 230 product references required by the production process and regrouping them in nearly identical product classes, this list of items had 193 entries for a total of 553,000 units (liters, kg) or objects (drums, sprays, boxes,...). This product list represents about 1.5% of the total input mass with 8,400 different packagings accounting for nearly 15% of all the solid waste. It is very difficult to get a precise

information on the actual content of each item because most of these inputs are delivered by distributors who get them from companies which either pack or prepare the final product with components delivered by one or more transformer (chemical plant, refinery,...).

To enter the adequate information in the LCI, the 193 items were regrouped in 19 families of generic products (→ *Table 3*). Of the total mass of products, we discarded some comparatively innocuous items of the various family, such as string, adhesive tape, demineralised water or salt to melt the snow on the premises. This represents 0.74% of the total mass of secondary products inputs and 0.0111% of the total mass of inputs – paper included (→ *Table 4*).

cedures and/or the equipments can also contribute to the reduction of some environmental impacts due to plant and the delivery system.

The economics of these possible improvements have yet to be investigated thoroughly, including in the analysis, the commercial impacts of a new image of the product quotidien.

The impact categories, that have been selected in this study, follow mainly the classification of the 1992 Guide to Environmental LCA of Products proposed by CML-TNO-B&G [11]. We used only those impacts categories for which we had output data and which we considered relevant to this case study (→ *Table 5*):

Table 4: Relative importance of the primary and secondary inputs

Products	weight percentage of the total inputs	weight percentage of total waste
primary products	98.5% of the total inputs	generate 85% of solid waste
secondary products	1.5% of the total inputs	generate 15% of solid waste
neglected comparatively innocuous "various"	0.0111% of the total inputs	

For each family of generic products, we determined:

- the physical and chemical characteristics and the average composition,
- the origin (country and distance between the distributors and the plant),
- the different uses in the plant,
- the different modalities of treatment and disposal of the used products and effluents,
- the risk and toxicity [6],
- the environmental impacts.

All the data for both primary and secondary products were entered in the LCI to evaluate the environmental impacts. Our data sources are references [8,10-16].

3 The Impact Assessment

The inventory process generates too much data for an easy interpretation. The impact analysis reduces the total number of parameters to consider. This means that the use of materials, the energy consumption and the emissions are converted into contributions to environmental impact categories [11]. For a given functional unit, the set of figures associated to each impact category describes the environmental profile.

- The comparison between different environmental profiles achieved by changing some inputs (type of paper, ink composition ...) provides information for the reduction of some environmental impacts of the quotidien.
- The comparison between different environmental profiles achieved by changing the printing and distribution pro-

Table 5: List of impact criteria taken into consideration in the LCA analysis

Input parameters	Output parameters
- Depletion of abiotic resources - Gross energy value for input production , printing, delivery and disposal of the quotidien - Water intake	- Acidification potential - Eutrophication potential - Global warming potential - Human toxicity potential - Photochemical oxidant potential - Waste production - Ecotoxicity potential

4 Results

In this section, only the aggregated results of the LCA are shown. To obtain these findings, the results of the Life Cycle Inventories for 4 different quotidien:

- M_1 – actual 1995 newspaper Le MONDE
- M_2 – improved version of Le MONDE using both products with better environmental performances and a better plant control.
- M_3 – actual newspaper Le MONDE with 41.6% less unsold circulation,
- M_4 – actual newspaper Le MONDE with 83.2% less unsold circulation,
- were aggregated according to the list of impact criteria presented previously.

M_1 results correspond to the 1995 data of the quotidien as defined in **section 2.2 and 2.3.**

To develop the improved M_2 version of Le MONDE, we studied:

- 19 different types of paper (paper types are presented in Table 6)
- 5 different types of inks,
- 2 printing processes with and without photosensitive films,
- 2 packaging processes.

The M_2 version is achieved using simultaneously the type of paper, the inks, the printing plate and the packaging material which have the lowest environmental impact as defined in section 3. For all these products an LCA has been carried out. Some results are reported in **Figures** 5 and 6 and **Table** 6 for paper identification. The selected products, for the improved version, are:

- paper using thermo mechanical pulp (TMP) and 66% of deinked pulp, to replace the actual paper which uses only 50% of deinked pulp. 100% deinked paper is not fit for newspaper printing because it does not resist the mechanical tensions due to the high paper speed (around 10 m/s)
- black and coloured inks elaborated with rape seeds oil [13,14,15],
- printing plates made exclusively of recycled aluminium plates; presently, due to poor internal management, these plates are not returned to the producer. Using information of the BIR [10], we considered that under 1995 conditions only 40% of these plates were recycled [16],
- polyethylene film rolls with increased width and weight and a reduced thickness in order to reduce the packaging losses.

The production process, already improved by the use of new products generating less effluents and waste, is also modified through better operation controls on the uses of paper, solvents, detergents....

The M_3 and M_4 versions correspond to the 1995 quotidien, but with less unsold newspapers; the number of newspapers effectively sold remaining constant and equal to 76. Thus, as reported in **Table** 7, the amount of printed newspapers for:

- M_3 with 41.6% less unsold circulation (instead of 24 newspapers only 14 are returned to the NMPP), will be equal to 90 average quotidien,

Table 6: Paper Types

Identification	Paper quality
DIP 70% (coal)	24% spruce pressurized stone groundwood (PGW) + 70% deinked pulp (DIP) + 6% pine kraft pulp : heat generation from coal
DIP 60% (coal)	33% spruce (PGW) + 60% DIP + 7% pine kraft pulp : heat generation from coal
DIP 50% (coal)	42% spruce (PGW) + 50% DIP + 8% pine kraft pulp : heat generation from coal
Integr. PGW/DIP	Integrated newsprint mill using 34% spruce (PGW) + 66% (DIP) : heat generation from wood and fuel
DIP 71% (mix D)	23% spruce (PGW) + 71% DIP + 5% pine kraft pulp from outside : heat generation from average German sources
DIP 60% (mix D)	33% spruce (PGW) + 60% DIP + 7% pine kraft pulp from outside : heat generation from average German sources
PGW (energy coal)	90% spruce (PGW) + 10% pine kraft pulp from outside: heat generation from coal
Integr. TMP/DIP	Integrated newsprint mill using 34% spruce thermo mechanical pulp (TMP) + 66% (DIP) : heat generation from wood and fuel
Integr. TMP/DIPy2010	Integrated newsprint mill using 34% spruce (TMP) + 66% (DIP) : heat generation from wood and fuel : pollution control level 2010
integr. PGW/Cl2kappa 30	Integrated newsprint mill using 90% spruce (PGW) + 10% pine kraft pulp with chlorine : kappa (whiteness index) n° 30: heat generation from wood and fuel
integr. PGW/ECFkappa 18	90% spruce (PGW) + 10% pine kraft pulp elementary chlorine free (ECF): kappa n° 18 : heat generation from wood and fuel
PGW (energy gas)	90% spruce (PGW) + 10% pine kraft pulp from outside : heat generation from gas
integr. TMP/Cl2kappa 30	Integrated newsprint mill using 96% spruce (TMP) + 4% pine kraft pulp with chlorine : kappa n° 30 : heat generation from wood and fuel
integr.TMP/CGF 18ECF kappa 18	Integrated newsprint mill using 96% spruce (TMP) + 4% pine kraft pulp (ECF) : kappa n° 18 : heat generation from wood and fuel
TMP (coal)	100% spruce (TMP) : heat generation from coal
TMP(peat)	100% spruce (TMP) : heat generation from peat
integr.TMP/CGF y2010 (ECF futur)	Integrated newsprint mill using 96% spruce (TMP) + 4% pine kraft pulp (ECF) : kappa n° 18 : heat generation from wood and fuel : pollution control level 2010
TMP (mix D)	100% spruce (TMP) : heat generation from average fuels used in Germany
TMP (mix F)	100% spruce (TMP) : heat generation from average fuels used in Finland

PGW = pressurized stone groundwood; DIP = deinked pulp; TMP = thermo mechanical pulp; ECF = elementary clorine free; kappa = whiteness index; from outside = produced in another plant

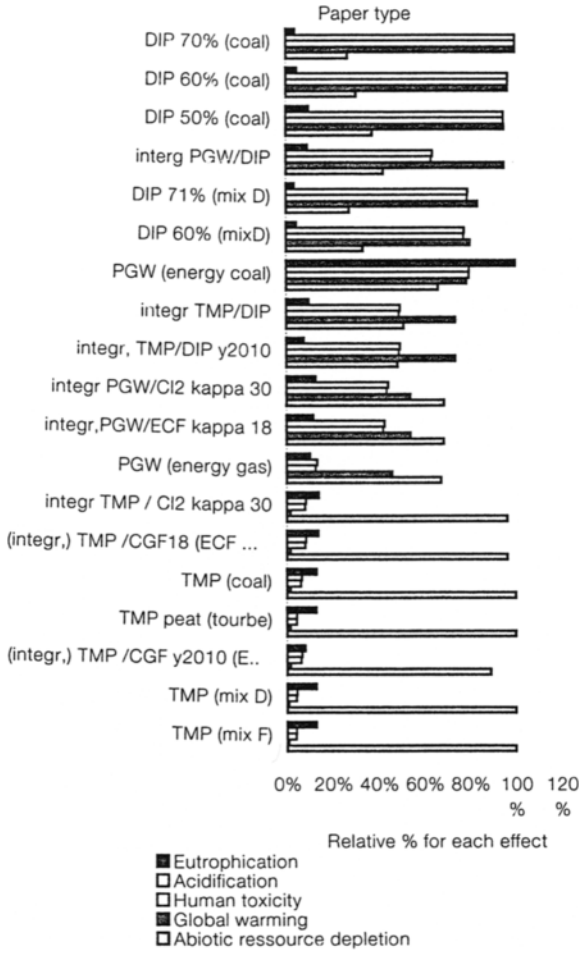

Fig. 5: Papers LCA analysis

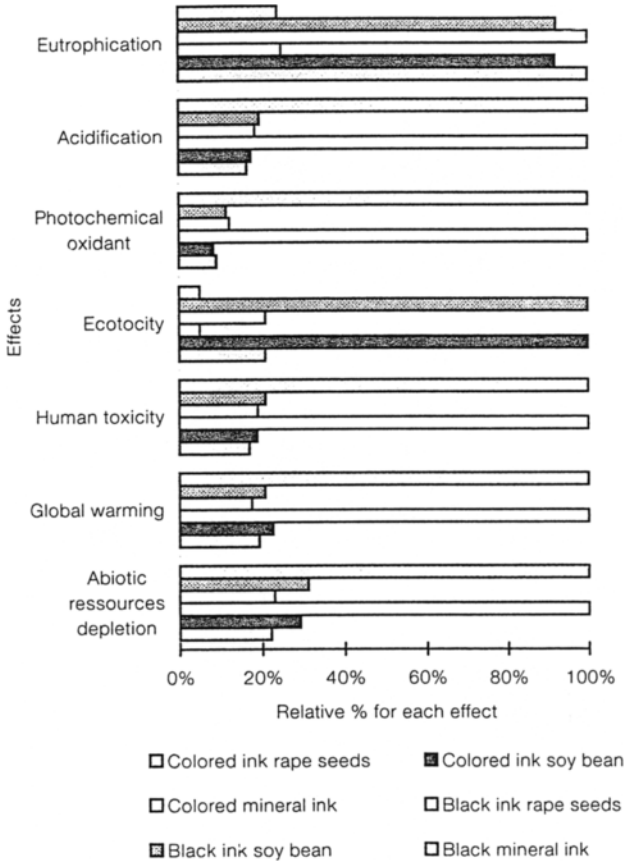

Fig. 6: Inks LCA analysis

- M_4 with 83.2% less unsold circulation (only 4 newspapers are returned to the NMPP), will be equal to 80 average quotidien.

Table 7: Number of printed and sold newspapers in each study case

Newspaper identification	M_1	M_2	M_3	M_4
number of printed "quotidien"	100	100	90	80
number of sold "quotidien"	76	76	76	76

4.1 Analysis of the input parameters and waste production

The results are presented using percentage points of the maximum value obtained by M_2, M_3 and M_4 using as reference M_1. Table 8 reports the relative mass (kg) and energy (GJ) values.

4.1.1 Depletion of abiotic ressources

The relative effect score obtained by M_2, M_3 and M_4 using as reference M_1, has been calculated applying CML (1996) criteria [12]. The improvement, achieved for newspaper M_2, is mainly due to the 100% aluminium recycling in the print-

Table 8: Fluctuations of some environmental parameters of newspapers M_1, M_2, M_3, M_4

Parameters relative variations in % of the maximum value	Newspaper			
	M_1	M_2	M_3	M_4
Abiotic resources	100	« 1	nearly 100	nearly 100
Gross energy	100	15 to 16	> 99	> 99
Waste	100	44 to 45	99	98
Water	100	8	> 99	99

ing plate fabrication process: only a negligeable amount of bauxite is needed. However it must be remembered that this is amplified because we allocate all the plates to one functional unit.

4.1.2 Gross relative energy values

Production and disposal of the quotidien M_1 consumes the most energy through the following three main activities by order of importance:

- production of primary and secondary inputs,
- newspapers printing,
- transportation of inputs and waste.

The impact of newspaper distribution between the plant and the readers which has not been considered, would not modify this result.

- Newspaper M_2 has the lowest energy consumption because:
- less energy is required in the plates production process using recycled aluminium
- less energy is required to produce the vegetal inks,
- photosensitive plastic films have been eliminated,
- consumption is smaller so fewer materials are needed and transported.

Newspapers M_3 and M_4 have reduced energy consumption, compared to M_1, because the total production is smaller so fewer materials are needed and transported.

4.1.3 Waste production

The highest reductions in industrial waste production, in the case of newspaper M_2, are due to:

- the plate production: 51% less waste are generated when all plates are recycled,
- including vegetal residues, the vegetal ink production does not increase the waste generated,
- the waste generated by the energy system is reduced 84% but as
- more nuclear energy is used, slightly more radiactive waste is produced so there is a small increase of the radioactivity released.

4.1.4 Water intake

The improvement, in water intake for newspaper M_2, results mainly from the elimination of the photosensitive polyethylene films which require water for both production and treatment.

4.2 Analysis of the output parameters

The results are presented using percentage points of the highest value of the effect score [11] calculated for M_2, M_3 and M_4, for the same total amount of sold newspapers, using as reference M_1 except for the ecotoxicity potential.

4.2.1 Acidification, eutrophication, global warming, human toxicity and photochemical oxidant potentials

- Quotidien M_1 is the reference for all these potentials because its elaboration consumes the most primary and secondary inputs, generates the most waste and the highest transportation requirements.

- The environmental impacts of M_3 and M_4 are not seriously reduced even with a 10% and 20% reduction of the number of printed quotidien. The relative improvements of the different effect scores are not better than 4% for M_3 and 8% for M_4. This is mainly due to the inefficiency of the actual printing process which compensates the reduction in inputs. However, if we had been able to take into account the transportation between the plant and the readers, the relative improvements would have been higher.

- Comparison between the environmental impacts of the improved quotidien M_2 and the actual quotidien M_1 shows that the relative improvements vary (→ *Table 9*).

In **Table 10**, we analyse and quantify some of the effects of the improvements that have been suggested for the development of a newspaper with better environmental characteristics.

Locally, the improved process with vegetal inks and a better control of the use of most secondary products (solvents, wetting products, sprays...) reduces the toxicity and the photochemical oxidant potentials of the atmospheric effluents. This is of great importance for the plant operators but the global effects of these actions are not very important.

4.2.2 Ecotoxicity potential

The improved version M_2 of Le MONDE appears with the highest ecotoxicity potential due to the use of inks prepared with vegetal oil. The production of these oils from soya beans or rape seeds requires phytosanitary products, part of which contributes to the contamination of the environment. It means also that it is very likely that the farmers do not follow the biocide producers recommendations.

Newspapers M_1, M_3 and M_4, whose printing process uses only different amounts of mineral oil, have thus a much lower ecotoxicity potential – about 98% less (→ *Table 9*).

Table 9: Fluctuations of the output parameters of newspapers M_1, M_2, M_3, M_4

Relative values of the output parameters in % of the maximum value	Newspaper			
	M_1	M_2	M_3	M_4
acidification potential	100	19	99	98
eutrophication potential	100	49	96	92
global warming potential	100	68	97	94
human toxicity potential	100	18	99	98
photochemical oxidant potential	100	4	> 99	> 99
ecotoxicity potential	< 2	100	< 2	< 2

Table 10: Qualitative and quantitative effects of the main improvements

Improvement	Qualitative effect due to to each improvement separately		Quantitative effect difference in% between M_1 and M_2 due to each improvement separately		Global effect on
plate production with nearly 100% recycled aluminium	decrease of	• SO_x	- 90%		acidification & human toxicity
		• NO_x	- 86%		
		• NH_3	- 68%		
		• HCl	- 87%		
		• HF ___	- 99%		___ global warming
		• N_2O ___	- 76%		eutrophication & photochemical oxidation
		• COD	nearly - 100%		
		• no non methanic VOC	nearly - 100%		
use of paper with 66% recycled newspapers	Decrease of	• CO_2 ___	- 26%		___ global warming
	Decrease of	• Phosphorus	- 77%		
	Increase of	• COD	+ 85%		eutrophication
		Nitrogen	+ 50%		
removal of photosensitive plastic film	decrease of	• CO_2	- 100%		
		• NO_x ___	- 100%		___ global warming & acidification
		• VOC.	- 100%		human toxicity & photochemical oxidation
			black ink	colour ink	
use of vegetal inks	decrease of	• SO_x	- 84%	- 85%	
		• NH_3	- 67%	- 67%	acidification & human toxicity
		• HCl	- 93%	- 86%	
		• HF	- 99%	- 80%	___
		• CH_4	- 88%	- 81%	global warming & photochemical oxidation
		• CO_2	- 87%	- 85%	
		• VOC	- 90%	- 92%	___
		• CO	- 19%	- 12%	air toxicity
		• H_2S	- 85%	- 85%	___
		• NO_x ___	- 85%	- 83%	
		• CN	- 85%	- 84%	
		• NO_3	- 68%	- 97%	
		• Pb	- 78%	- 78%	water toxicity
		• hydrocarbons	- 56%	- 73%	
		• F	-75%	- 75%	
	increase of	• NH_4	+ 2670%	+ 2700%	
		• PO_3 ___	+ 35%	+ 35%	___
		• COD	+ 260%	+ 244%	eutrophication
		• Nitrogen	+ 2500%	+ 2500%	

COD = Chemical Oxygen Demand; VOC = Volatil Organic Compound

4.3 Input and output changes due to each improvement

In order to evaluate the specific changes induced by each modification separately – aluminium recycling, new paper, new inks and removal of photosensitive films – we compared the characteristics of 4 newspapers M_{1a}, M_{1b}, M_{1c}, M_{1d} to the real one. Newspapers M_{1a}, M_{1b}, M_{1c}, M_{1d} are produced under the same conditions as M_1 except for one change as indicated in **Table 11**. The inputs and ouputs environmental parameters of newspapers M_{1a}, M_{1b}, M_{1c}, M_{1d} are compared to the same M_1 parameters in **Tables 12** and **13**.

5 Key Findings

The analysis we carried out on the actual newspaper M_1 for a full operation year – 1995 – allows the following comments:

- the production management control procedures of the printing process are reponsible for most of the environmental impacts of the plant. In particular, the waste of paper (nearly 4% of the annual input) and aluminium plates (nearly 8 tons) as well as the excessive use of solvents, detergents, sprays,... must be improved.

Table 11: Characteristics of newspapers M_{1a}, M_{1b}, M_{1c}, M_{1d}

Newspaper	Modification with regard to the process used to produce the 1995 newspaper M_1
M_{1a}	only modification : all photosensitive aluminium plates are 100 % recycled.
M_{1b}	only modification : the paper type (DIP 50% (coal)) used in the production process is replaced by paper type (integr. TMP/DIP).
M_{1c}	only modification : the photosensitive plastic films used in the photo engraving process have been eliminated
M_{1d}	only modification : the mineral inks are replaced by rape seed oil inks.

Table 12: Fluctuations of some environmental parameters of newspapers M_1, M_{1a}, M_{1b}, M_{1c}, M_{1d}

Parameters relative variation in % of the maximum value	Newspaper				
	M_1 Actual newspaper	M_{1a} with recycled Al plates	M_{1b} with new paper type	M_{1c} without photosensitive films	M_{1d} with vegetal inks
Abiotic resources	100	« 1	100	nearly 100	100
Gross energy	100	22.5	100.5	93	> 99
Waste	100	49	98	97	nearly 100
Water	100	100	100	6	102

Table 13: Fluctuations of the output parameters of newspapers M_1, M_{1a}, M_{1b}, M_{1c}, M_{1d}

Relative values of the output parameters in % of the maximum value	Newspaper				
	M_1 Actual newspaper	M_{1a} with recycled Al plates	M_{1b} with new paper type	M_{1c} without photosensitive films	M_{1d} with vegetal inks
acidification potential	100	25	98	97	99
eutrophication potential	100	46	105	99	100
global warming potential	100	87	96	87	98
human toxicity potential	100	25	98	97	99
photochemical oxidant potential	100	7	100	97	100
ecotoxicity potential	< 2	< 2	< 2	< 2	100

The values reported in **Tables 12** and **13** confirm the results reported in **section 4.1** and **4.2**. They confirm also that our decision to allocate the daily consumption of plates and films to one functional unit amplifies their global environmental impacts and stresses the importance of a better management of these items.

- better paper, modification of the photoengraving process, new vegetal inks, better residues disposal procedures and the buying of secondary products in bulk would reduce even more the impacts without any plant modification.

Thus, the global environmental impacts of the operation, maintenance, preparation and packaging of Le MONDE could be seriously reduced without incurring in new investments.

The analysis of newspapers M_3 and M_4 corresponding to newspaper M_1 with an improved distribution, reducing the unsold circulation by 40% and 80%, proves that a better circulation does not reduce significantly (8% or less) the relative effect score of the different environmental impacts because the effects of the production management are predominant.

The development of an improved version M_2 of Le MONDE is based on the main results obtained for M_1. The actions recommended to achieve a reduced environmental impact of the newspaper are listed in **Table 14.**

Obviously the best results would be achieved combining the improved version M_2 with the improved distribution M_4. The economical effects of version ($M_2 - M_4$) would be very important. Yet the probability of achieving these results is very low, because Le MONDE management appears to have very little control on both the production and the distribution.

From this analysis, it appears that an improvement of the enviromental impacts of newspaper Le MONDE depends more on the good will of all the partners (management, trade unions, supervisors, workers, suppliers...) involved in the manufacturing process than on technical decisions. Hopefully these results will induce some effective actions.

It appears also that a Life Cycle Assessment study is not only useful for identifying and assessing the environmental impacts of a product or service throughout all stages of its life cycle but also to improve the management control of the manufacturing plant.

Table 14: Proposed actions to improve the newspaper Le MONDE

Actions	Improvements	Main induced effects on inputs	Global effects on outputs
management improvements	• reduction of the avoidable internal paper losses through - a better stock management - a better preparation of the paper rolls - a better follow up of partially used rolls	- 4.5% less paper losses of which 0.5% are due to the use of vegetal inks	} waste reduction
	• adequate ink and solvent residues disposal procedures • use of products delivered mainly in bulks • adequate recovering and disposal of packagings	- 10% less product losses,	
	• reprocessing 100% of the aluminium plates	- nearly 100% less bauxite	- acidification - human toxicity - global warming { eutrophication - photochemical oxidation decrease
product improvements	• use of paper rolls with 66% of recycled newspapers	- cost reduction	acidification, global warming biotic ressource decrease
	• use of black and colored rape seeds oil inks: - vegetal inks contain 2% of COV compared with 28% for mineral inks, - vegetal inks have also the following properties: brighter, better covering effect, more hard-wearing, less messy, produce less emulsion with the wetting products	- 10% less inks - 30% less solvents - 20%less detergents - 20% less wetting products - 10% less water circuit treatment products	ecotoxicity & eutrophication increase toxicity decrease
process improvements	• removal of the plastic photosensitive films through direct impression of the photo-sensitive aluminium plates.	- 47% less chemicals to treat the photosensitive layer	- global warming - acidification, {- human toxicity - photochemical oxidation decrease
	• replacement of the actual low density PE rolls by larger ones in the final packaging of newspapers.	- 10% less PELD consumption	waste decrease

The necessary confidentiality for Le MONDE specific data does not allow to report any cost analysis taking into account the proposed actions.

Acknowledgements

This work has been funded between 1994 and 1997 by the French National Agency for Technological Research – ANRT under a research agreement between the newspaper Le MONDE and the University Paris 7 – Denis Diderot.

The authors thank Mr G. LOMBARDO from the CTP, Ms S. GASSER from EDF, Mr G. VERMEERSCH from SOFIPROTEOL, Mr H. LECOULS from Elf ATOCHEM, Ms P. CORTIJO and Mr O. MULLER from ECOBILAN, Ms N. BŒGLIN from ADEME, for their useful informations for the newspaper LCA.

The author want also to thank Ms P. CORTIJO and Mr O. MULLER for their constructive review of the present paper.

6 References

[1] BOUSTEAD, I.: Life Cycle Analysis. Colloque Audits d'environnement- Bilan écologique des produits, 40 p., Nov 30. Paris, France (1992)

[2] ROUSSEAUX, P.: Evaluation Comparative de l'Impact Environnemental Global (ECIEG) du Cycle de Vie des Produits. PhD Thesis, (n° 93 ISAL 0037), INSA Lyon, France (1993)

[3] BLOUET, A.; RIVOIRE E.: L'ECOBILAN, Dunod Paris, (1995)

[4] KLUPPEL, H-J.; SAUR, K.: Special Issue: Current LCA-ISO Activities. Int. J. LCA 2 (1) 2-4 (1997)

[5] KLUPPEL, H-J.: Goal and Scope definition and Life Cycle Inventory Analysis. Int. J.LCA 2 (1) 5-8 (1997)

[6] RAFENBERG, C.: Life-Cycle Assessment of the newspaper Le MONDE. PhD thesis, University of Orléans, (1998) – R&D study financed by Le MONDE and the National Association for Technological Research

[7] OJD: Office Juridique de la Diffusion (office in charge of assessing the actual circulation of all newspapers in France), monthly and annual reports, Paris, France, (1995, 1996)

[8] KCL-ECO, ECODATA: registered trademarks of the Finish Pulp and Paper Research Institute, SF- 02151 Espoo, Finland

[9] RICE, G.; CLIFT, R.; BURNS R.: LCA Software Review – Comparison of currently available european. LCA software Int. J.LCA 2 (1) 53-59 (1997)

[10] DATA SOURCES: publications and/or private communications from:

- ADEME: French Agency for Energy Economy and Environment, Paris, France
- BIR: International Recycling Office (Bureau International du Recyclage), Brussels, Belgium
- BUWAL: Swiss Federal Office of Environment, Forests and Landscape – FOEFL, Berne, Switzerland
- CEA: Atomic Energy Commission, France
- CETIOM: Oleaginous R&D and Information Center, Paris, France
- CTP: Technical Center for Paper, Grenoble, France
- ECOBILAN SA, Paris, France
- EDF: French Power Company – R&D Center of Renardières, 77, France
- EFPG-INPG: Paper Engineering School of the Polytechnical Institute of Grenoble, France
- ELF – ATOCHEM, Pierre Bénite – Lyon, France
- ETH: Federal Polytechnical University, Zurich, Switzerland
- IFRA: INCA-FEIJ Resarch Association, Darmstadt, Germany
- Manufacturers: Agfa, Ink producers,...
- ONIDOL: Oleaginous National Interprofessional Organization, Paris, France
- Papier Carton: Paper Carboard Review, Paris, France
- PWMI: European Center for Plastics in the Environment of the APME, Association of Plastics Manufacturers in Europe
- SETAC: Society of Environmental Toxicology and Chemistry, Washington, USA
- Surfactant Study Group, Germany

[11] HEIJUNGS, R.; GUINÉE, J.B.; HUPPES, G.; LANKREIJER, R.M.; UDO DE HAES; WEGENER SLEESWIJK, A.; ANSEMS, A.M.M.; EGGELS, P.G.; VAN DUIN, R.; GOEDE, H.P.: Environmental Life Cycle Assessment of Products, Background and Guide. Center of Environmental Science (CML), NL – 2300 RA Leiden (1992)

[12] GUINÉE, J.B, HEIJUNGS, R.; VAN OERS, L.; VAN DE MEENT, D.; VERMEIRE, T.; RIKKEN, M.: LCA Impact assessment of toxic releases. Center of Environmental Science (CML), NL – 2300 RA Leiden (1996)

[13] FUCHS, B.; THOYER, B.: IFRA special report 1.12. IFRA publications services, INCA-FEIJ Resarch Association, Darmstadt, Germany (1995)

[14] SABIN, P.; BENJELLOUN-MLAYAH, B.; DELMAS, M.: Utilisation de Colza et Tournesol dans les encres offset. OCL 2 (5) 401-408, (1995)

[15] ERHAN, S.Z.; BAGBY, M.O.: Vegetable-oil-based printing ink formulation and degradation. Industrial Crops and Products 3 (4) 237-246, (1995)

[16] HABERSATTER, K.; FECKER, I.: Ökoinventare für Verpackungen. Schriftenreihe Umweltn 250/I BUWAL, Berne, Switzerland (1996)

Received: April 1st, 1998
Accepted: May 29th, 1998